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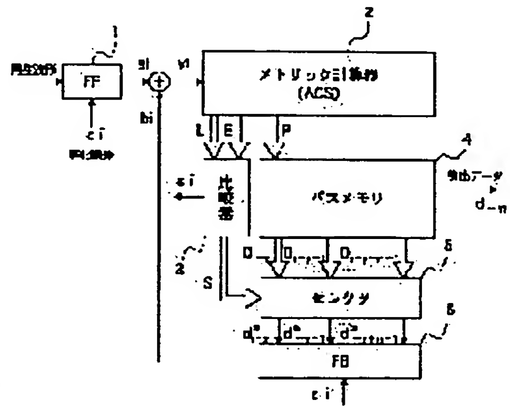
(54) INFORMATION REPRODUCING DEVICE USING FEEDBACK FILTER

(57)Abstract:
PROBLEM TO BE SOLVED: To improve the error rate by selecting a data stream corresponding to a path providing a minimum path metric on the basis of a state transition diagram introduced from an output of an impulse response waveform and a depth of a tree so as to obtain a compensation value for equalization.
SOLUTION: A metric computing device 2 outputs an equivalent error E, a path metric L of a survival path and a survival path P corresponding to each state on the basis of a state transition diagram. A comparator 3 outputs a path state numbers providing a minimum value to the path metric L and an equivalent error εi corresponding to a most probable path. A selector 5 uses the state number S to select one of a plurality of data streams D corresponding to the survival path P stored in a path memory 4 and to output a tentatively detected data stream d*. A feedback filter 6 obtains and outputs a compensation value to equalize a trailing edge of an impulse response of an output of a feedforward filter 1 to '0' on the basis of the tentatively detected data stream d*.



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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the information regenerative apparatus which equipped data detection with the description especially about the information regenerative apparatus which reproduces the digital information recorded on the magnetic disk, the magnetic tape, the optical disk, etc.
[0002]
[Description of the Prior Art] PRML (Partial Response Maximum Likelihood) which combined the partial response method and the maximum-likelihood-detection method as the record data playback approach in digital storage regenerative apparatus, such as a magnetic disk drive and an optical disk, -- law is used. Since it furthermore corresponds to high recording density-ization in recent years, in magnetic recording, the method which combined the modulation technique which can extend the distance between the minimum signs to EEPR4 method which is the high order PRML method is proposed. (Jaekyun Moon and Barrett Brickner, "Maximum TransitionRun Codes for Data Storage Systems", IEEE Transactions on Magnetics, vol.32, no.5, and Sept.1996 reference).
[0003] Moreover, apart from the PRML method, the RAM-DFE (Decision Feedback Equalizer) method and the FDTS/DF (FixedDelay Tree Search/Decision Feedback) method are also examined as a detector using a feedback filter.
[0004] To the maximum-likelihood-detection method time amount until data are identified becomes unfixed, the FDTS/DF method restricts path length, is the approach of choosing the smallest pass pass metric with the limited path length, and tends to correspond to high recording density-ization which this mentioned above.
[0005] Drawing 11 is the block diagram showing the configuration of the equipment by the FDTS/DF method.
[0006] After a playback wave is set to ai (i is time of day) by passing along the feedforward filter 1101, it is inputted into the FDTS detector 1111, being used as yi through an adder. Although FDTS detector 1111 output di-gamma +1 is used as detection data, it is inputted into the delay element 11071 at coincidence. Two or more delay elements are prepared, and 11071, 11072, --, 1107n are connected serially, and it is outputted to the feedback filter (FB) 6 as output di-gamma [of each n delay element], di-gamma -1, --, data stream D corresponding to [to this time i] each condition at i-gamma to the i-gamma+n-1 time in di-gamma-n +1.
[0007] bi which is feedback filter 1106 output is inputted into the above-mentioned adder, is added with feedforward filter 1101 output ai, and is set to yi.
[0008] This conventional example is outputted in quest of delay ****** data in the FDTS detector 1111 at the gamma-1 (gamma is the tree depth) time.
[0009] Each of drawing 12 and drawing 13 is drawing showing the judgment approach of FDTS, and an impulse response.

[0010] An impulse response is a response to record data "1." In magnetic recording, the dipulse which are two continuous solitary waves which the polarity reversed as a playback wave is supported. Drawing 12 and drawing 13 are the examples of the tree depth gamma= 2. As shown in drawing 12 , in i time, it compares in quest of branch metric and pass metric to four pass (tree), and the pass which gives smallest pass metric is determined. And it outputs as judgment data which decided the data at the i-gamma +1 time in the pass.

[0011] As an input value [as opposed to the feedback filter 1106 for the detection data stream before i-gamma +1 time called for as mentioned above], wave compensation at the following i+the 1 time is performed.

[0012] Drawing 13 is the example of an impulse response wave. With the feedforward filter 1101, the output value in an identification point is set to "1", and the former output value is equalized in "0" rather than it. Moreover, identification henceforth of is carried out to "0" with the feedback filter 1106 from gamma bit delay **** from the identification point. Thereby, an identification wave will be expressed with the superposition of the output value (1 and a) of left-behind gamma bit (here 2 bits), and metric count and data detection are performed according to the judgment approach shown in drawing 12 .

[0013]

[Problem(s) to be Solved by the Invention] the FDTS/DF method -- data detection -- FDTS -- law is used. This approach restricts path length, and since it is what asks for pass metric from the limited pass, an error rate property may get worse rather than a maximum-likelihood-detection method.

[0014] Moreover, when it is going to use a maximum-likelihood-detection method, the feedback loop cannot be operated within the time amount (clock) restricted from time amount until data are identified being unfixed, and it being less than the delay by which detection data were restricted, and being unable to ask.

[0015] This invention is made in view of the trouble which a Prior art which was mentioned above has, the feedback loop can be operated in the amount of delay decided while using the maximum-likelihood-detection method, and it aims at realizing the information regenerative apparatus using the highly precise feedback filter with which the error rate has been improved.

[0016]

[Means for Solving the Problem] The information regenerative apparatus using the feedback filter by this invention The feedforward filter which performs identification of the first transition section of the impulse response of a playback wave, sets the output value in an identification point to "1", and sets the output value before it to "0", The feedback filter with which the trailing-edge section after tree depth gamma bit delay ****** is compensated from said identification point, From the identification wave which said feedforward filter output and the feedback filter output piled up The identification error [as opposed to each identification reference level value based on the state transition diagram led from the wave output of tree depth gamma and an impulse response] E The metric calculator which chooses the pass with which it asks for branch metric to each branch, and pass metric, pass metric to each condition is compared, and pass metric serves as min as survival pass to the condition, Input the survival pass chosen by said metric calculator, and this time i is received. The pass memory to which n data of i-gamma to i-gamma+n-1 time output the value of the last stage as data stream D corresponding to each condition, and detection data, The comparator which asks for the pass with which pass metric serves as the minimum value out of the survival pass to each condition searched for by said metric calculator, The selector which inputs data stream D which said pass memory outputs, chooses the data stream corresponding to the pass which gives minimum pass metric called for in said comparator, and is outputted to said feedback filter, It provides and said feedback filter is characterized by calculating the amount of compensation for identification based on the data stream chosen in said selector.

[0017] In this case, it is good also as having the delay element which is made into what has pass

memory length shorter than the number of input data of a feedback filter, holds the detection data which said pass memory outputs, and is outputted to a feedback filter.
[0018] Also in which [above] case, a selector is good also as performing adaptive equalization of a feedforward filter and a feedback filter using the identification error which chose the identification error corresponding to the pass used as minimum pass metric, and was this chosen out of the identification error corresponding to each survival pass.
[0019] Moreover, said feedback filter and a metric calculator set tree depth gamma to 2, and a metric calculator is good also as making the state transition diagram of two conditions correspond to the playback wave which said feedforward filter output and the feedback filter output piled up, and performing maximum likelihood detection.
[0020] Moreover, said feedback filter and a metric calculator set tree depth gamma to 3, and a metric calculator is good also as making the state transition diagram of four conditions correspond to the playback wave which said feedforward filter output and the feedback filter output piled up, and performing maximum likelihood detection.
[0021] Furthermore, said feedback filter and a metric calculator set tree depth gamma to 4, and a metric calculator is good also as making the state transition diagram of eight conditions correspond to the playback wave which said feedforward filter output and the feedback filter output piled up, and performing maximum likelihood detection.
[0022] The information playback approach using the feedback filter of this invention Perform identification of the first transition section of the impulse response of a playback wave, and the output value in an identification point is set to "1." The 1st step which compensates the trailing-edge section after tree depth gamma bit delay ****** from an identification point. and is made into an identification wave while setting the output value before it to "0", The identification error [as opposed to each identification reference level value based on the state transition diagram led by the wave output of tree depth gamma and an impulse response from said identification wave] E The 2nd step which chooses the pass with which it asks for branch metric to each branch, and pass metric, pass metric to each condition is compared, and pass metric serves as min as survival pass to the condition, This time i is received based on the survival pass chosen at said 2nd step. The 3rd step which generates n data stream D corresponding to each condition of i-gamma to i-gamma+n-1 time by which the data of the last stage are used as detection data. The 4th step which asks for the pass with which pass metric serves as the minimum value out of the survival pass to each condition searched for at said 2nd step, The 5th step which chooses the data stream corresponding to the pass which gives minimum pass metric called for at said 4th step based on n data stream D generated at said 3rd step, It is characterized by having the 6th step which calculates the amount of compensation for the identification performed at said 1st step based on the data stream chosen in said selector.
[0023] Although pass metric count is closed even by tree depth gamma and minimum pass metric is called for in a "operation" FDTS. detector, maximum likelihood detection is performed like a PRML method in this invention.
[0024] In this invention, based on the state transition diagram obtained from a gamma value and an impulse response in a metric calculator, branch metric and pass metric are calculated first, and the survival pass to each condition is determined. However, like a general PRML method, an integral value does not become, but criterion level is a real number value, and can be given to arbitration. Pass memory is the same configuration as a general PRML method, and can perform maximum likelihood detection.
[0025] In order to perform waveform equalization, a feedforward filter and a feedback filter are used. Like the FDTS/DF method, with a feedforward filter, identification of the first transition section of an impulse response is performed, and the output value before it is set to "0" for the output value in an identification point as "1." On the other hand, the feedback filter is compensating the trailing-edge section after gamma bit delay ****** from the identification point.

[0026] The above waveform-equalization actuation is the same as the FDTS/DF method. The detection value corresponding to the probable pass at present is used for the input value over the feedback filter in this invention as a temporary detection data stream not from a FDTS detection result but from two or more detection data streams recorded on pass memory. This temporary detection data stream is a detection data stream corresponding to that pass, when it asks for the pass which compares pass metric of the survival pass corresponding to each condition, and gives minimum pass metric.

[0027] If the above-mentioned actuation is summarized, the state transition diagram which is to the base of maximum likelihood detection will be determined in a metric calculator from a gamma value and an impulse response wave, and will be recorded on pass memory. A comparator calculates the pass metric minimum value corresponding to two or more survival pass recorded on pass memory. A selector chooses the probable data stream (data stream corresponding to the pass of pass metric min) at present from data stream D of pass memory as temporary detection data by the pass metric minimum value calculated by the comparator. Selected temporary detection data are inputted into a feedback filter. Compensation of the first transition section to an impulse response and the trailing-edge section is performed using this feedback filter and a feedforward filter.

[0028] As mentioned above, in this invention, since it replaced with the FDTS detecting method used by the FDTS/DF method and the maximum-likelihood-detection method (the Viterbi detecting method) was used, the error rate has been improved. Moreover, by using the probable data stream at present as temporary detection data from the data stream recorded on pass memory, feedback actuation can be performed in the decided amount of delay, and it has become a highly precise detector.

[0029]

[Embodiment of the Invention] Next, the example of this invention is explained with reference to a drawing.

[0030] Drawing 1 is the block diagram showing the important section configuration of the information regenerative apparatus using the feedback filter by this invention, and shows the configuration of the part which generates detection data from the playback wave acquired from the reproducing head which is a detector.

[0031] In the data detecting element which is a FDTS/DF method, this example is replaced with a FDTS detector and consists of the metric calculator (ACS) 2 used by a PRML method etc., the feedforward filter (FF) 1 prepared using the pass memory 4 and a comparator 3, a selector, and a feedback filter 6.

[0032] the wave from which identification of the first transition section is carried out to "0" from the identification point of an impulse response wave with the feedforward filter (FF) 1, and the playback wave acquired from the reproducing head (un-illustrating) starts to "1" in an identification point -- it is outputted as ai (i is time of day). It is outputted to the metric calculator (ACS circuit) 2, the output ai of this feedforward filter 1 being added with the output bi of the feedback filter (FB) 6, and being used as yi. By adding the output ai of the feedforward filter 1 with the output bi of the feedback filter 6, the trailing-edge section from the number of bits (tree depth gamma) which started and was defined from the location serves as a wave by which identification was carried out "0." The definition of tree depth gamma is the same as that of the definition in a FDTS/DF method, and the number of bits to the location which is the feedback filter 6 and is equalized from an identification point is shown.

[0033] By the metric calculator 2, it asks for the identification error E over each identification reference level value, branch metric to each branch, and pass metric from Input yi (identification wave) based on the state transition diagram led from the wave output of tree depth gamma and an impulse response. And pass metric to each condition is compared and the pass with which pass metric serves as min is chosen as survival pass to the condition.

[0034] The metric calculator 2 performs the above actuation, outputs pass metric L of the identification error E corresponding to each condition, and survival pass to a comparator 3, and outputs the survival pass P (selection result) to the pass memory 4.

[0035] In a comparator 3, the minimum value of the survival pass to each condition pass metric [L] is calculated, and identification error epsiloni corresponding to the probable pass is chosen from the state number S and identification error E, and it outputs to the feedback filter 6 at the same time it outputs the state number S corresponding to the pass which gives the minimum value to a selector 5.

[0036] In a selector 5, one is chosen from multiple-data-stream D corresponding to [survive and] pass recorded on pass memory using the selected state number S, and temporary detection data stream d* is outputted. Temporary judging data stream d* is gamma bit delay ****** earlier data train from this time i, and outputs the trailing-edge section (from a standup to gamma bit delay ****** (or before)) of the impulse response of FF output to "0" in quest of the compensation value for considering as identification based on this d* in FB. On the other hand, the last stage output of pass memory is used as final detection data d, without using temporary detection data.

[0037] Next, actuation of this example is explained.

[0038] First, the principle of operation of the feedforward filter 1 in drawing 1 and the feedback filter 6 is explained. The impulse response wave corresponding to some gamma values is shown in drawing 2 . "1" of record data is made to correspond to the dipulse (continuous wave form of two solitary waves where polarities differ) in a playback wave here, supposing a magnetic recording medium. That is, it changes to record data (1-D), and the solitary wave is made to correspond to the point that translation data is set to "**1." gamma is similarly defined as the tree depth in FDTS/DF, and from an identification point, gamma bit is the feedback filter 6 and it is used for maximum likelihood detection, without carrying out identification.

[0039] Drawing 2 (a) is [gamma= 3 and drawing 2 (c) of gamma= 2 and drawing 2 (b)] the examples of an identification wave (impulse response) of gamma= 4.

[0040] In each impulse response wave, the feedforward filter (FF) 1 performs identification to the first transition section from the time (identification point) of going up from 0 to +1 first, and all are equalized in "0."

[0041] The wave output values a, b, and c after the identification point shown in drawing 2 are any value, and it is also possible that identification of it is carried out with the feedforward filter 1 since the value of these a, b, and c to determine in consideration of a property, an error rate, etc. of a playback wave is determined by the feedforward filter 1, if a playback wave does not change.

[0042] On the other hand, the feedback filter (FB) 6 performs identification to the trailing-edge section after gamma time from an identification point, and all are equalized in "0." As long as there is no judgment error, the feedback filter 6 is not influenced of a noise, in order to compensate based on the judgment result in an identification point. The impulse response wave by which identification was carried out is acquired for all the bits excluding a part for gamma bit from the identification point by the above "0."

[0043] The identification wave y acquired as mentioned above is inputted into the metric calculator (ACS circuit) 2 of the maximum ** (Viterbi) detector shown in drawing 1 .

[0044] The state transition diagram which serves as a base for performing metric count of maximum likelihood detection in this example at drawing 3 is shown. Drawing 3 (a) is [gamma= 3 and drawing 3 (c) of gamma= 2 and drawing 3 (b)] the examples of gamma= 4. These state transition diagrams are constituted based on the impulse response wave shown in drawing 2 , and the value shown in each branch expresses detection data and an identification reference value. Based on such a state transition diagram, from a difference (identification error E) with an identification reference value, it asks for branch metric and pass metric, and the survival pass to each condition is determined. Although it survives to pass memory and Pass P is only outputted in the conventional ACS circuit, pass metric L to each survival pass and the identification error E are outputted to coincidence by the metric calculator (ACS circuit) 2 in this example.

[0045] Outputted pass metric L and the identification error E are inputted into the comparator 3 shown in drawing 1 . In the comparator 3, a comparison pass metric [corresponding to each condition / L] is

performed, and it is asking for the state number S corresponding to the pass which gives the minimum pass metric value. Moreover, with this state number S, the value which corresponds from the identification error E is chosen, and it is outputting as identification error epsiloni. feedforward -- a filter -- (-- FF --) -- one -- and -- feedback -- a filter -- (-- FB --) -- six -- immobilization -- a parameter -- a filter -- it is -- a case -- identification -- an error -- epsilon -- i -- being unnecessary -- although -- adaptive equalization -- carrying out -- a case -- this identification error epsiloni -- using -- the parameter of the feedforward filter (FF) 1 and the feedback filter (FB) 6 -- receiving -- adaptive equalization -- carrying out -- serially -- it can change . As it is made in agreement with the value which the adaptive equalization of the feedforward filter (FF) 1 set the first transition section of an impulse response to "0", and showed the wave output value of gamma bit by drawing 2 from the identification point, it is changing a parameter, and the adaptive equalization of the feedback filter (FB) 6 is changing a parameter so that the trailing-edge section of an impulse response may be set to "0."
[0046] The configuration of the pass memory 4 is fundamentally [as the pass memory in the conventional PRML method] the same. Changed parts are that the value in the first rank is changed based on a state transition diagram, and that n of i-gamma to i-gamma+n-1 time are outputted as an input candidate to the feedback filter (FB) 6 to this time i as data stream D corresponding to each condition in the contents of the pass memory 4. the first rank of the pass memory 4 -- by modification of a value, since the selector of the first rank becomes meaningless, the delay element and selector of the first rank can also be deleted.
[0047] In a selector 5, probable temporary judging data stream d* is chosen at present from such data stream D by the state number S. The feedback filter (FB) 6 outputs the compensation value for waveform equalization (compensation of the trailing-edge section) based on this data stream d*. On the other hand, the detection data d as a detector of this example are outputted not from above-mentioned temporary detection data d* but from the last stage of pass memory. Therefore, sufficiently long pass memory is taken, and if pass is completed, a maximum-likelihood-determination result will be obtained.
[0048] In this example, a gamma value can set up two or more values. Moreover, it sets up beforehand and the wave output value after the identification point of an impulse response can also be maintained by performing adaptive equalization to the feedforward filter (FF) 1. What is necessary is just to create the state transition diagram for maximum likelihood detection with these values.
[0049] Next, the case of the tree depth gamma= 3 is explained more concretely as an example about actuation of the example mentioned above.
[0050] Drawing 4 is drawing showing the identification process of a playback wave corresponding to record data "1" (identification process of an impulse response), and explains an identification process in detail using drawing 4 .
[0051] A continuous-line wave is the impulse response of the feedforward filter (FF) 1. With the feedforward filter (FF) 1, the time (identification point) of an output value starting is set to "1", and the first transition section is equalized in 0 from there. At this time, identification about the trailing-edge section is not performed rather than an identification point. Since the feedback filter (FB) 6 in this example is outputting the compensation value by the delay of gamma bit, it can be compensated from an identification point to gamma bit delay ******. It is an identification wave after compensation with the feedback filter (FB) 6 that each arrow head at the time shows the amount of compensation, and is shown by the dotted line. The value of a and b is determined by arbitrary playback wave-like properties etc. Moreover, the gestalt of the feedforward filter (FF) 1 and the feedback filter (FB) 6 is also arbitrary.
[0052] Since the feedforward filter (FF) 1 just equalizes a playback wave like the continuous line of drawing 4 , an analog filter, its transversal filter, etc. are usable. Since the feedback filter (FB) 6 just outputs the compensation value for identification from a detection data stream, it can use a transversal

filter and a RAM table.
[0053] Metric count is [that what is necessary is just to carry out based on the state transition diagram shown in drawing 3 (b)] fundamentally [as the conventional ACS circuit] the same. A difference is the point of outputting pass metric value L0-3 corresponding to four survival pass, and identification difference E0-3 in addition to survival pass P0-3 corresponding to each condition.
[0054] The configuration of the state number S which asks for smallest pass metric and corresponds to drawing 5 from these pass metric L0-3, and the comparator 3 which searches for the identification error epsilon for adaptive equalization is shown. The comparator 3 consists of a comparator 10 and a selector (S) 9. A comparator 10 outputs the state number S which compares four pass metric L0-3 and gives the minimum value. The selector (S) 9 is outputting Es as identification error epsiloni from four input values (identification error E0-3) based on a state number S.
[0055] The configuration of the pass memory 4 and a selector 5 is shown in drawing 6 . The configuration of pass memory is fundamentally [as the conventional PRML method] the same. However, if a state transition diagram 3 (b) is followed, since the selector of the first rank will serve as selection from the same value, the delay element and selector of the first rank are omitted. Moreover, corresponding to the several n input data bit of the feedback filter (FB) 6, n steps of data stream D is outputted outside. The data D from each stage (at each time) are four corresponding to a condition, and are judgment data corresponding to the survival pass of each condition.
[0056] In the selector 5, the data in each time are chosen with a state number S, and probable temporary judging data stream d* is outputted at present. Final detection data are outputted from the back end of the pass memory 4. At this time, when pass memory length is longer than the number of input data of the feedback filter (FB) 6, the configuration shown in drawing 6 may be used, but when short, it is [that what is necessary is to hold detection data using the delay element and just to input into the feedback filter (FB) 6] good also as such a configuration.
[0057] Drawing 7 is drawing for explaining the process in which a temporary judging data stream is determined, and drawing 7 (a) is the example of a trellis diagram. The continuous line shows the survival pass in i time. When such survival pass is called for, data as shown in drawing 7 (b) are recorded on pass memory. If survival pass merges, all the judgment data in the time are in agreement. Here, it has merged at the i-3 time and the detection data before it are decided. When L1 becomes the minimum value among pass metric L0-3 of the survival pass in this time, the data stream corresponding to the condition S1 of having surrounded by the dotted-line frame is chosen, and it is used as an input to the feedback filter (FB) 6.
[0058] By the above, feedback can be hung by the delay of gamma clock like a FDTS/DF method. Drawing 8 shows the identification reference value and branch metric for performing metric count. Based on these formulas, branch metric and pass metric count is performed, and maximum likelihood detection is performed. The constant derived from the identification reference values R and R can reduce the amount of operations by calculating beforehand.
[0059] Next, the 2nd example of this invention is explained with reference to drawing 9 and drawing 10 .
[0060] These make the 1st comparator 3 in an example, pass memory 4, and selector 5 the comparator 903, the pass memory 904, and the selector 905 from which a configuration differs, drawing 9 is drawing showing the configuration of the comparator 903 in the 2nd example of this invention, and drawing 10 of this example is drawing showing the configuration of the pass memory 904 in the 2nd example of this invention, and a selector 905. Since the configuration of those other than these is the same as that of the 1st example, only these configurations are explained.
[0061] The number of clocks required of the operation gestalt shown in drawing 5 and drawing 6 since a signal is transmitted in the feedback loop is only 1 clock. This one clock needs to perform count of an identification wave, branch metric and pass metric count, selection of survival pass, minimum pass metric detection, and selection of temporary detection data, it is necessary to calculate the amount of compensation with the feedback filter 6 (FB) further, and a circuit-burden is very large. Then, in the

2nd example, it makes it possible to increase the number of clocks required since a signal is transmitted in the feedback loop.
[0062] The configuration and actuation of this example are concretely explained with reference to drawing 9 and drawing 10 . the comparator 903 of this example — setting — a delay element (D) -- 9071 and 9072 are prepared and the delay element (D) 9073 is formed in the pass memory 904. by each of these delay elements (D), 1 bit is delayed, respectively in pass metric L which is the output of the ACS circuit 2, the identification error E, and the selection branch (survival pass) P, instead, 1 bit of data stream D which is an output from the pass memory 904 is shifted, and it is outputted (1:00 point -- bringing forward). By the above, it can have the allowances of one clock in time, and the feedback loop can be calculated. However, by this approach, since the output from a number-of-stages eye with pass memory low 1 bit is used for temporary judging data d*, precision has fallen.
[0063] What is necessary is to shift the output location of the data D shown in drawing 10 in the number-of-stages direction where pass memory is low, instead just to insert a delay element in somewhere, in order to acquire k bits (clock) time allowances. It is made for the timing of each operation not to shift then. The feedback loop will operate with a 1+k clock by this. Moreover, since the identification error for performing adaptive equalization may also shift from i time, adaptive equalization is also performed according to it. Generally by this approach, the feedback loop can be operated by the delay of gamma-1 bit of maxes.
[0064]
[Effect of the Invention] Since this invention is constituted as explained above, the effectiveness indicated below is done so.
[0065] In the FDTS/DF method, it is effective in the ability to make an error rate improve by replacing with FDTS detection and using the maximum-likelihood-detection method (the Viterbi detecting method) used by the PRML method.

[Translation done.]

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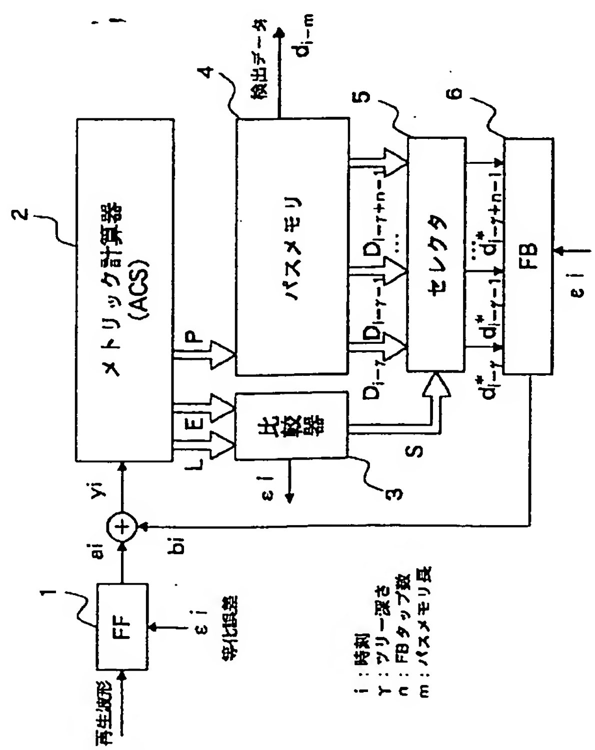
(54)【発明の名称】　フィードバックフィルタを用いた情報再生装置

(57)【要約】
【課題】　ＦＤＴＳ／ＤＦ法では、データ検出にＦＤＴＳ法を用いている。この方法は、パス長を制限して、限られたパスに対してパスメトリックを求めているため最尤検出法よりもエラーレート特性が悪化する可能性がある。最尤検出法を用いると限られた時間（クロック）内でフィードバックループを動作させることができない。
【解決手段】　ＦＤＴＳ検出器の代わりに、最尤検出器を用いる。さらに、フィードバックループを動作させるために、パスメモリに記録された複数のデータ列から、現時点で最も確からしいデータ列を選択し、仮検出データ列としてＦＢ（フィードバックフィルタ）に入力する。このＦＢとＦＦ（フィードフォワードフィルタ）を用いて再生波形を等化する。最終的な検出データは、パスメモリ最終段出力を用いる。



記録密度化に対応しようとするものである。

【０００５】図１１はＦＤＴＳ／ＤＦ法による装置の構成を示すブロック図である。

【０００６】再生波形はフィードフォワードフィルタ１１０１を通ることによりａｉ（ｉは時刻）とされた後に加算器を介してｙｉとされてＦＤＴＳ検出器１１１１に入力される。ＦＤＴＳ検出器１１１１出力$d_{i-\gamma+1}$は検出データとされるが、同時に遅延素子１１０７$_1$に入力されている。遅延素子は複数設けられており、１１０７$_1$，１１０７$_2$，…，１１０７$_n$がシリアルに接続され、ｎ個の遅延素子それぞれの出力$d_{i-\gamma}$，$d_{i-\gamma-1}$，…，$d_{i-\gamma-n+1}$は、現時点ｉに対して、ｉ－γからｉ－γ＋ｎ－１時点の各状態に対応するデータ列Ｄとして、フィードバックフィルタ（ＦＢ）６へ出力されている。

【０００７】フィードバックフィルタ１１０６出力であるｂｉは上記の加算器に入力され、フィードフォワードフィルタ１１０１出力ａｉと加算されてｙｉとされる。

【０００８】本従来例は、ＦＤＴＳ検出器１１１１においてγ－１（γはツリー深さ）時点遅れた検出データを求めて出力している。

【０００９】図１２および図１３のそれぞれは、ＦＤＴＳの判定方法およびインパルス応答を示す図である。

【００１０】インパルス応答は、記録データ“１”に対する応答である。磁気記録では、再生波形として極性の反転した連続する２つの孤立波であるダイパルスに対応している。図１２および図１３はツリー深さγ＝２の例である。図１２に示すように、ｉ時点において、４つのパス（ツリー）に対するブランチメトリックとパスメトリックを求めて比較し、最も小さなパスメトリックを与えるパスを決定する。そして、そのパスにおけるｉ－γ＋１時点のデータを確定した判定データとして出力する。

【００１１】上記のようにして求められたｉ－γ＋１時点以前の検出データ列をフィードバックフィルタ１１０６に対する入力値として、次のｉ＋１時点の波形補償を行う。

【００１２】図１３は、インパルス応答波形の例である。フィードフォワードフィルタ１１０１により、識別点での出力値を“１”とし、それよりも以前の出力値を“０”に等化している。また識別点からγビット遅れた点から以降は、フィードバックフィルタ１１０６により“０”に等化されている。これにより等化波形は、残されたγビット（ここでは２ビット）の出力値（１とａ）の重ね合わせで表されることになり、図１２に示される判定方法に従ってメトリック計算とデータ検出が行われる。

【００１３】

【発明が解決しようとする課題】ＦＤＴＳ／ＤＦ法では、データ検出にＦＤＴＳ法を用いている。この方法は、パス長を制限するものであり、限られたパスに対してパスメトリックを求めるものであるため、最尤検出法よりもエラーレート特性が悪化する可能性がある。

【００１４】また、最尤検出法を用いようとする場合には、データが同定されるまでの時間が不定であり、検出データを限られた遅延以内で求めることができないことから限られた時間（クロック）内でフィードバックループを動作させることができない。

【００１５】本発明は上述したような従来の技術が有する問題点に鑑みてなされたものであって、最尤検出法を用いるとともに決められた遅延量でフィードバックループを動作させることができ、エラーレートが改善された高精度なフィードバックフィルタを用いた情報再生装置を実現することを目的とする。

【００１６】

【課題を解決するための手段】本発明によるフィードバックフィルタを用いた情報再生装置は、再生波形のインパルス応答の前縁部の等化を行い、識別点での出力値を“１”とし、それ以前の出力値を“０”とするフィードフォワードフィルタと、前記識別点からツリー深さγビット遅れた時点以降の後縁部の補償を行うフィードバックフィルタと、前記フィードフォワードフィルタ出力およびフィードバックフィルタ出力とが重ね合わされた等化波形から、ツリー深さγとインパルス応答の波形出力から導かれる状態遷移図に基づいて各等化基準レベル値に対する等化誤差Ｅ、各ブランチに対するブランチメトリック、および、パスメトリックを求め、各状態へのパスメトリックを比較し、パスメトリックが最小となるパスをその状態への生き残りパスとして選択するメトリック計算器と、前記メトリック計算器により選択された生き残りパスを入力し、現時点ｉに対して、ｉ－γからｉ－γ＋ｎ－１時点までのｎ個のデータが各状態に対応したデータ列Ｄおよび検出データとして最終段の値を出力するパスメモリと、前記メトリック計算器にて求められた各状態への生き残りパスの中からパスメトリックが最小値となるパスを求める比較器と、前記パスメモリが出力するデータ列Ｄを入力し、前記比較器にて求められた最小パスメトリックを与えるパスに対応するデータ列を選択して前記フィードバックフィルタへ出力するセレクタと、を具備し、前記フィードバックフィルタは、前記セレクタにて選択されたデータ列に基づいて等化のための補償量を求めることを特徴とする。

【００１７】この場合、パスメモリ長がフィードバックフィルタの入力データ数よりも短いものとされ、前記パスメモリが出力する検出データを保持してフィードバックフィルタへ出力する遅延素子を有することとしてもよい。

【００１８】上記のいずれの場合においても、セレクタは、各生き残りパスに対応する等化誤差の中から、最小パスメトリックとなるパスに対応する等化誤差を選択

タを用いた情報再生装置の要部構成を示すブロック図であり、検出器である再生ヘッドから得られた再生波形から検出データを生成する部分の構成を示している。

【００３１】本実施例は、ＦＤＴＳ／ＤＦ方式のデータ検出部において、ＦＤＴＳ検出器に代えて、ＰＲＭＬ方式などで用いられるメトリック計算器（ＡＣＳ）２とパスメモリ４を用いたものであり、この他に設けられたフィードフォワードフィルタ（ＦＦ）１、比較器３、セレクタおよびフィードバックフィルタ６から構成される。

【００３２】再生ヘッド（不図示）から得られた再生波形は、フィードフォワードフィルタ（ＦＦ）１によって、インパルス応答波形の識別点より前縁部が“０”に等化されて識別点で“１”に立ち上がる波形ａｉ（ｉは時刻）として出力される。このフィードフォワードフィルタ１の出力ａｉは、フィードバックフィルタ（ＦＢ）６の出力ｂｉと加算され、ｙｉとされてメトリック計算器（ＡＣＳ回路）２に出力される。フィードフォワードフィルタ１の出力ａｉはフィードバックフィルタ６の出力ｂｉと加算されることによって、立ち上がり位置から定められたビット数（ツリー深さγ）からの後縁部が“０”に等化された波形となる。ツリー深さγの定義は、ＦＤＴＳ／ＤＦ方式における定義と同様であり、識別点からフィードバックフィルタ６で等化する位置までのビット数を示している。

【００３３】メトリック計算器２では、ツリー深さγとインパルス応答の波形出力から導かれる状態遷移図に基づいて、入力ｙｉ（等化波形）から、各等化基準レベル値に対する等化誤差Ｅ、各ブランチに対するブランチメトリック、および、パスメトリックを求める。そして各状態へのパスメトリックを比較し、パスメトリックが最小となるパスをその状態への生き残りパスとして選択する。

【００３４】メトリック計算器２は以上の動作を行い、各状態に対応する等化誤差Ｅおよび生き残りパスのパスメトリックＬを比較器３へ出力し、生き残りパスＰ（選択結果）をパスメモリ４へ出力する。

【００３５】比較器３では、各状態への生き残りパスのパスメトリックＬの最小値を求め、最小値を与えるパスに対応する状態番号Ｓをセレクタ５へ出力すると同時に、その状態番号Ｓと等化誤差Ｅから、最も確からしいパスに対応する等化誤差εｉを選択してフィードバックフィルタ６へ出力する。

【００３６】セレクタ５では、選択された状態番号Ｓを用いてパスメモリに記録された生き残りパスに対応する複数のデータ列Ｄから１つを選択して仮検出データ列ｄ＊を出力する。仮判定データ列ｄ＊は、現時点ｉからγビット遅れた時点以前のデータ列であり、ＦＢでは、このｄ＊をもとに、ＦＦ出力のインパルス応答の後縁部（立ち上がりからγビット遅れた時点以前）を“０”に等化とするための補償値を求め出力する。一方、最終的な検出データｄとしては、仮検出データを用いずにパスメモリの最終段出力を用いる。

【００３７】次に本実施例の動作について説明する。

【００３８】まず、図１におけるフィードフォワードフィルタ１、および、フィードバックフィルタ６の動作原理を説明する。図２にいくつかのγ値に対応するインパルス応答波形を示す。ここでは磁気記録装置を想定し、記録データの“１”を再生波形におけるダイパルス（極性の異なる２つの孤立波の連続波形）に対応させている。つまり記録データに対して（１－Ｄ）変換を行ない、変換データが“±１”となる点に孤立波を対応させている。γはＦＤＴＳ／ＤＦにおけるツリー深さと同様に定義され、識別点からγビットがフィードバックフィルタ６で等化されずに最尤検出に利用される。

【００３９】図２（ａ）はγ＝２、図２（ｂ）はγ＝３、図２（ｃ）はγ＝４の等化波形（インパルス応答）の例である。

【００４０】それぞれのインパルス応答波形において、最初に０から＋１に上がる時点（識別点）から前縁部に対する等化をフィードフォワードフィルタ（ＦＦ）１で行ない、すべて“０”に等化している。

【００４１】図２に示された識別点以降の波形出力値ａ、ｂ、ｃは任意の値であり、再生波形の特性やエラーレートなどを考慮して決定すればよい、これらａ、ｂ、ｃの値は、再生波形が変化しなければ、フィードフォワードフィルタ１によって決定されるので、フィードフォワードフィルタ１によって等化されていると考えることもできる。

【００４２】一方、識別点からγ時点以降の後縁部に対する等化は、フィードバックフィルタ（ＦＢ）６によって行ない、すべて“０”に等化する。フィードバックフィルタ６は、識別点での判定結果をもとに補償を行なうため、判定誤りがない限りノイズの影響を受けない。以上によって、識別点からγビット分を除いたすべてのビットが“０”に等化されたインパルス応答波形が得られる。

【００４３】上記のようにして得られた等化波形ｙは、図１に示した最尤（ビタビ）検出器のメトリック計算器（ＡＣＳ回路）２に入力される。

【００４４】図３に、本実施例における、最尤検出のメトリック計算を行なうための基本となる状態遷移図を示す。図３（ａ）は、γ＝２、図３（ｂ）は、γ＝３、図３（ｃ）は、γ＝４の例である。これらの状態遷移図は、図２に示したインパルス応答波形を元に構成されており、各ブランチに示された値は、検出データと等化基準値を表している。このような状態遷移図に基づいて、等化基準値との差（等化誤差Ｅ）からブランチメトリック、および、パスメトリックを求め、各状態に対する生き残りパスを決定する。従来のＡＣＳ回路では、パスメモリに対して生き残りパスＰを出力しているだけである

タを状態番号Ｓによって選択し、現時点で最も確からしい仮判定データ列d˜を出力している。最終的な検出データは、パスメモリ４の後端から出力されている。このときパスメモリ長が、フィードバックフィルタ（ＦＢ）６の入力データ数よりも長い場合は、図６に示す構成でよいが、短い場合は、遅延素子を用いて検出データを保持しておき、フィードバックフィルタ（ＦＢ）６に入力すればよく、このような構成としてもよい。

【００５７】図７は仮判定データ列を決定する過程を説明するための図であり、図７（ａ）は、トレリス線図の例である。ｉ時点での生き残りパスを実線で示している。このような生き残りパスが求められているとき、パスメモリには、図７（ｂ）に示すようなデータが記録されている。生き残りパスがマージすると、その時点での判定データは、すべて一致する。ここでは、ｉ－３時点でマージしており、それ以前の検出データは確定している。現時点での生き残りパスのパスメトリック$L_{0\text{-}3}$のうち、最小値となったのがL_1であった場合、点線枠で囲んだ、状態Ｓ１に対応するデータ列が選択され、フィードバックフィルタ（ＦＢ）６への入力として用いられる。

【００５８】以上により、ＦＤＴＳ／ＤＦ方式と同様にγクロックの遅れでフィードバックを掛けることができる。図８は、メトリック計算を行うための、等化基準値とブランチメトリックを示している。これらの式にもとづいてブランチメトリック、および、パスメトリックの計算を行い最尤検出を行う。等化基準値Ｒおよび、Ｒから派生する定数は、あらかじめ計算しておくことによって演算量を減らすことができる。

【００５９】次に、本発明の第２の実施例について図９および図１０を参照して説明する。

【００６０】本実施例は、第１の実施例における比較器３、パスメモリ４およびセレクタ５をこれらとは構成が異なる比較器９０３、パスメモリ９０４およびセレクタ９０５としたものであり、図９は、本発明の第２の実施例における比較器９０３の構成を示す図であり、図１０は本発明の第２の実施例におけるパスメモリ９０４とセレクタ９０５の構成を示す図である。これら以外の構成は第１の実施例と同様であるため、これらの構成についてのみ説明する。

【００６１】図５および図６に示した実施形態では、フィードバックループを信号が伝わるために必要なクロック数は、わずか１クロックである。この１クロックで、等化波形の計算、ブランチメトリックとパスメトリックの計算、生き残りパスの選択、最小パスメトリックの検出、仮検出データの選択を行い、さらにフィードバックフィルタ６（ＦＢ）で補償量の計算を行う必要があり、回路的な負担が非常に大きい。そこで、第２の実施例においては、フィードバックループを信号が伝わるために必要なクロック数を増やすことを可能としている。

【００６２】本実施例の構成および動作について、図９および図１０を参照して、具体的に説明する。本実施例の比較器９０３においては、遅延素子（Ｄ）907_1、907_2が設けられ、パスメモリ９０４には遅延素子（Ｄ）907_3が設けられている。これらの各遅延素子（Ｄ）により、ＡＣＳ回路２の出力であるパスメトリックＬ、等化誤差Ｅ、選択ブランチ（生き残りパス）Ｐをそれぞれ１ビット遅延し、代わりに、パスメモリ９０４からの出力であるデータ列Ｄを、１ビットずらして（１時点早めて）出力している。以上により、時間的に１クロックの余裕をもってフィードバックループの演算を行うことができる。ただし、この方法では、仮判定データd˜は、パスメモリの１ビット低い段数目からの出力を用いているので精度が落ちている。

【００６３】ｋビット（クロック）の時間的余裕を得るためには、図１０に示したデータＤの出力位置をパスメモリの低い段数方向へずらし、その代わりにどこかに遅延素子を挿入すればいい。そのときそれぞれの演算のタイミングがずれないようにする。これによりフィードバックループは、１＋ｋクロックで動作することになる。また適応等化を行うための等化誤差もｉ時点からずれる可能性があるので適応等化もそれに合わせて行う。この方法では、一般に最大γ－１ビットの遅れでフィードバックループを動作させることができる。

【００６４】

【発明の効果】本発明は以上説明したように構成されているので、以下に記載する効果を奏する。

【００６５】ＦＤＴＳ／ＤＦ法において、ＦＤＴＳ検出に代えて、ＰＲＭＬ方式で用いる最尤検出法（ビタビ検出法）を用いることにより、エラーレートを改善させることができる効果がある。

【図面の簡単な説明】

【図１】本発明の検出器の全体構成を示すブロック図

【図２】本発明における、各γに対するインパルス応答を示す図

【図３】本発明における、各γに対する状態遷移図

【図４】本発明における、γ＝３に対する波形等化法を示す図

【図５】図１の比較器３において、γ＝３とした場合の詳しい構成を示す図

【図６】図１のパスメモリ４およびセレクタ５において、γ＝３とした場合の詳細な構成を示す図

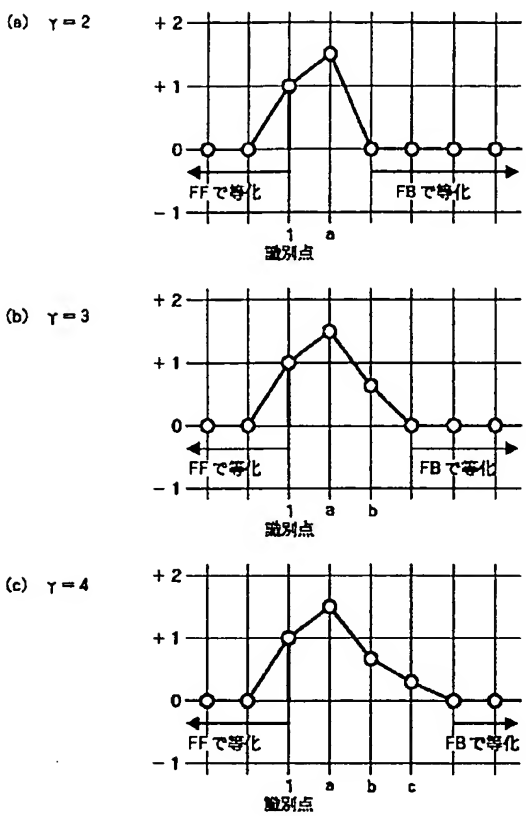
【図７】図６のパスメモリ４およびセレクタ５の動作の例を示す図

【図８】図１のＡＣＳ回路２において、γ＝３とした場合のメトリック計算式を示す図

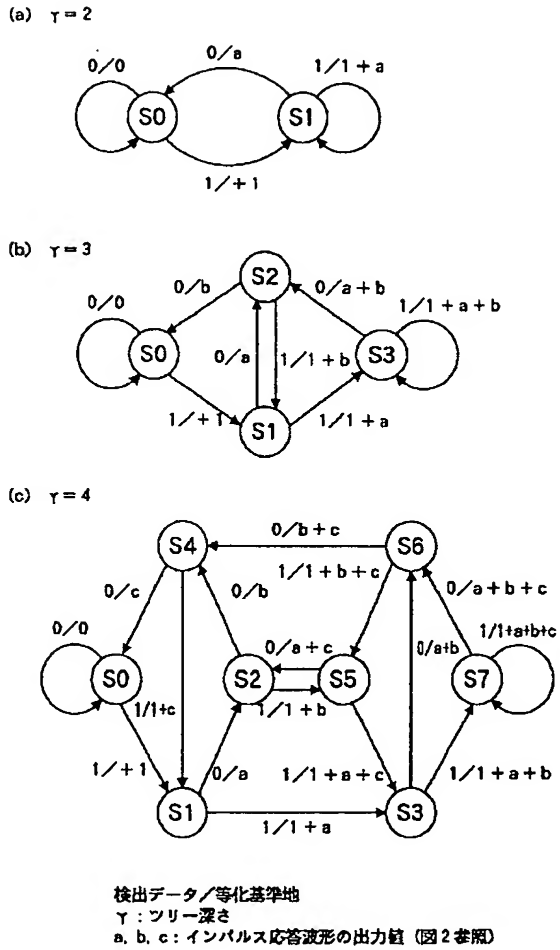
【図９】本発明の他の構成における、γ＝３での比較器３の構成を示す図

【図１０】本発明の他の構成における、γ＝３でのパスメモリ４とセレクタ５の構成を示す図

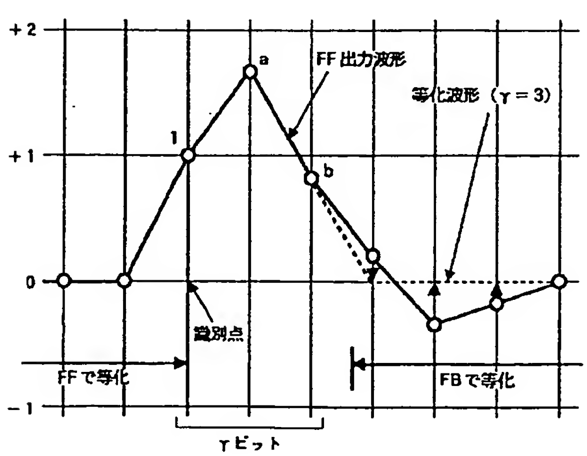
【図２】


(a) γ＝2
(b) γ＝3
(c) γ＝4
+2
+1
0
−1
FFで等化
FBで等化
1 a b c
識別点

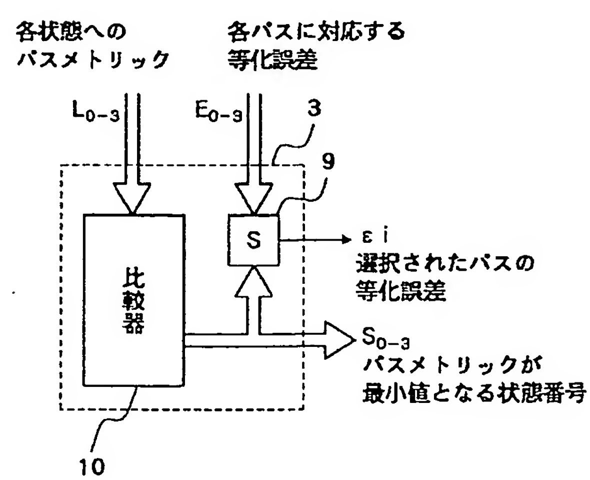
【図３】


(a) γ＝2
0/0
0/a
1/1＋a
1/＋1
S0
S1
(b) γ＝3
0/b
0/a＋b
1/1＋a＋b
0/a
1/1＋b
1/＋1
1/1＋a
S0 S1 S2 S3
(c) γ＝4
0/b＋c
1/1＋b＋c
0/c
0/b
0/a＋b＋c
1/1+a+b+c
0/a＋c
0/a+b
1/1+c
1/1＋b
0/a
1/＋1
1/1＋a＋c
1/1＋a＋b
1/1＋a
S0 S1 S2 S3 S4 S5 S6 S7
検出データ／等化基準地
γ：ツリー深さ
a, b, c：インパルス応答波形の出力値（図２参照）

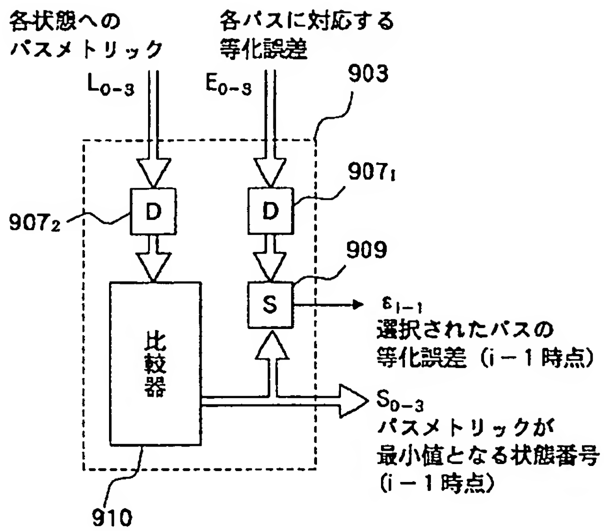
【図４】


+2
+1
0
−1
a
1
b
FF出力波形
等化波形（γ＝3）
識別点
FFで等化
FBで等化
γビット

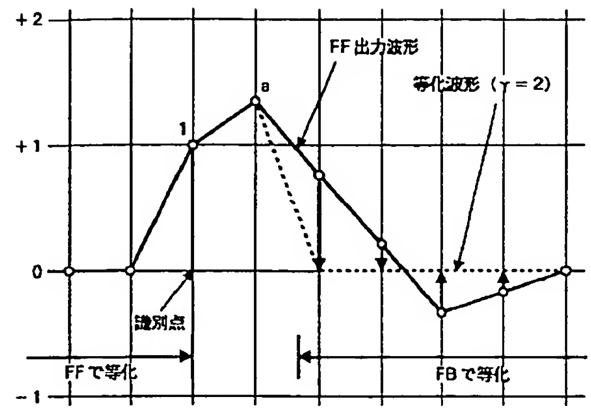
【図５】


各状態への
パスメトリック
各パスに対応する
等化誤差
L_{0-3}
E_{0-3}
3
9
S
比較器
εi
選択されたパスの
等化誤差
S_{0-3}
パスメトリックが
最小値となる状態番号
10

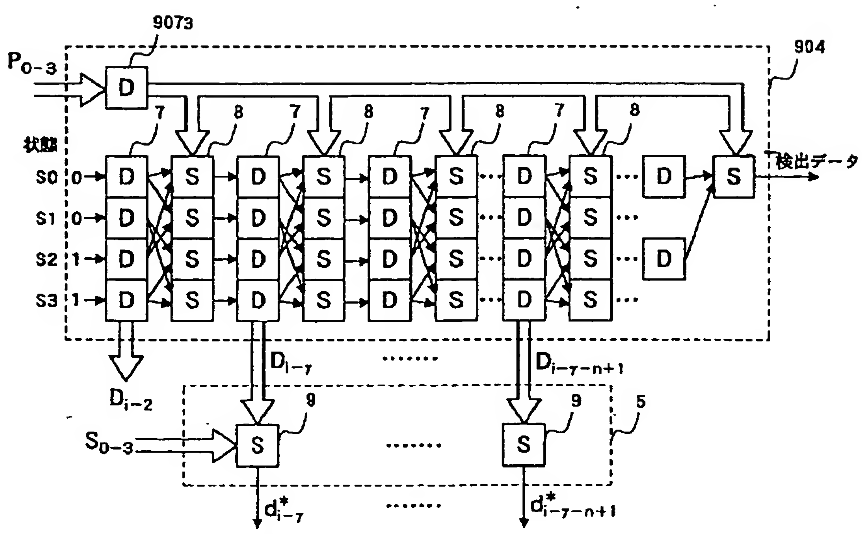
【図９】



【図１３】



【図１０】



n：FBのタップ数
γ：ツリー深さ（ここでは、γ＝3）